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ULTRASOUND TEMPERATURE CURRENT METER
[CHO-ONPA ONDO RYUSOKU KEI]

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1. NAME OF INVENTION *

ULTRASOUND TEMPERATURE CURRENT METER

[Claims]

【Claim 1】 An ultrasound temperature current meter having,

on the outer wall surface of the pipe, 1st and 2nd ultrasound transducers facing each other in a vertical direction relative to the longitudinal direction of the pipe on the outer wall surface of the pipe;

on the outer wall surface of the pipe, 3rd and 4th ultrasound transducers facing each other in a diagonal direction relative to the longitudinal direction of the pipe;

an acoustic velocity measuring device that measures the acoustic velocity of the fluid flowing in said pipe based on the transmission time of ultrasound wave transmitted from said 1st ultrasound transducer to said 2nd ultrasound transducer and on the transmission time of ultrasound wave transmitted from said 1st ultrasound transducer which is reflected by the inner wall of said pipe and returns to said 1st ultrasound transducer;

a temperature measuring device which measures the temperature of the fluid flowing in said pipe based on the acoustic velocity measured by this acoustic velocity measuring device; and

a current velocity measuring device which measures the current velocity of the fluid flowing in said pipe based on the difference between the transmission time of ultrasound wave from said 3rd ultrasound transducer to said 4th ultrasound transducer and the transmission time of ultrasound

* Claim and paragraph numbers correspond to the one in the foreign text.

wave from said 4th ultrasound transducer to said 3rd ultrasound transducer and the acoustic velocity measured by said acoustic velocity measuring device.

[DETAILED DESCRIPTION OF THE INVENTION]

【0001】 【Technical Field of the Invention】

This invention relates to an ultrasound temperature current meter which uses ultrasound wave to measure temperature and current velocity of the fluid flowing in the pipe.

【0002】 【Prior Art】

Conventionally, as a measuring device to measure current velocity flowing in a pipe, ultrasound current meter is known having a 1st and a 2nd ultrasound sensors placed on the outer wall surface of the pipe and facing each other in a diagonal direction relative to the longitudinal direction of the pipe, which measures the current velocity based on the difference between the transmission time of ultrasound wave from the 1st ultrasound sensor to the 2nd ultrasound sensor and the transmission time of ultrasound wave from the 2nd ultrasound sensor to the 1st ultrasound sensor and the preset acoustic velocity of the fluid.

【0003】 Further, since the acoustic velocity in the fluid varies according to the temperature of the fluid, a method to measure the current velocity has been proposed, such as the temperature compensation type current meter under the JP-A (Tokkai) H02-111617, which measures the temperature of the fluid by an appropriate temperature measuring element

and then compensates the acoustic velocity based on the measured temperature so that the current velocity can be obtained without being influenced by the temperature.

【0004】 【Problem to be Resolved by the Invention】

However, with such conventional ultrasound wave current meter which uses a temperature measuring element to measure the fluid temperature in order to do away with any influences on the acoustic velocity variation from the fluid temperature, it was necessary to bore a hole in the pipe to setup the temperature measuring element. Further, due to a delay in measurement by the temperature measuring element, it was not possible to obtain accurate measurement when the temperature and the current velocity varied widely over time. The objective of this invention is to provide an ultrasound temperature current meter which can measure temperature and current speed of a fluid with ease and with high accuracy.

【0005】 【Means of Solving the Problem】

In order to solve these problems, this invention uses a pair of ultrasound transducers, placed on the outer wall surface of the pipe, facing each other in a vertical direction relative to the longitudinal direction of the pipe to measure the acoustic velocity and the temperature of the fluid flowing in the pipe.

【0006】 Namely, the ultrasound temperature current meter of this invention has

on the outer wall surface of the pipe, 1^{st} and 2^{nd} ultrasound

transducers facing each other in a vertical direction relative to the longitudinal direction of the pipe on the outer wall surface of the pipe;

on the outer wall surface of the pipe, 3rd and 4th ultrasound transducers facing each other in a diagonal direction relative to the longitudinal direction of the pipe;

an acoustic velocity measuring device that measures the acoustic velocity of the fluid flowing in the pipe based on the transmission time of ultrasound wave transmitted from the 1st ultrasound transducer to the 2nd ultrasound transducer and on the transmission time of ultrasound wave transmitted from the 1st ultrasound transducer which is reflected by the inner wall of the pipe and returns to the 1st ultrasound transducer;

a temperature measuring device which measures the temperature of the fluid flowing in the pipe based on the acoustic velocity measured by this acoustic velocity measuring device; and

a current velocity measuring device which measures the current velocity of the fluid flowing in the pipe based on the difference between the transmission time of ultrasound wave from the 3rd ultrasound transducer to the 4th ultrasound transducer and the transmission time of ultrasound wave from the 4th ultrasound transducer to the 3rd ultrasound transducer and the acoustic velocity measured by the acoustic velocity measuring device.

【0007】 With the ultrasound temperature current meter of this invention, the transmission time of the ultrasound wave in the fluid is determined after eliminating any influence from the thickness of the pipe

by subtracting transmission time of the ultrasound wave sent from the 1st ultrasound transducer which reflects on the inner wall of the pipe and returns to the 1st ultrasound transducer from the transmission time of the ultrasound wave sent from the 1st ultrasound transducer to the 2nd ultrasound transducer.

【0008】 Since the ultrasound wave transmitted from the 1st ultrasound transducer travels in the vertical direction relative to the flow direction of the fluid flowing in the pipe, the transmission time is not influenced by the current velocity of the fluid. Thus, an accurate acoustic velocity can be obtained by the ultrasound wave in the fluid, and the temperature of the fluid can be obtained from this acoustic velocity.

【0009】 Therefore it is possible to obtain the acoustic velocity and temperature easily and with high accuracy without having to boring a hole in the pipe for the temperature measuring element, and without any influence from the thickness of the pipe or from variation in the thickness of the pipe due to temperature variation.

【0010】 Further, by measuring the current velocity of the fluid flowing in the pipe based on the difference between the transmission time of the ultrasound wave from the 3rd ultrasound transducer to the 4th ultrasound transducer and the transmission time of the ultrasound wave from the 4th ultrasound transducer to the 3rd ultrasound transducer and the above-mentioned measured acoustic velocity, the current velocity can be measure accurately even when the temperature and the current velocity

varies widely over time.

【0011】 【Embodiment of the Invention】

Figure 1 is a block diagram showing skeleton framework of the ultrasound temperature current meter under one embodiment of this invention. This ultrasound temperature current meter is composed from sensors 1 through 3, a switching device 4, a transceiver 5, a gate circuit 6, a counter 7, a calculation unit 8, and a control unit 9.

【0012】 The sensors 1 through 3 are for transmitting and receiving ultrasound wave under this embodiment. Figure 2 shows actual configuration and their placement on the pipe. Sensor 1 has piezoelectric elements 21 and 23, while sensor 2 and 3 have piezoelectric elements 22 and 24, respectively. The piezoelectric element 21 is driven by the send signal outputted from the transceiver 5 via the switching device 4, sends ultrasound wave to the pipe 30 side, and, in addition, receives ultrasound wave coming from the pipe 30 side, converts it to an electric signal, and outputs it as a receive signal.

【0013】 Further, sensors 1 through 3 are placed on the outer wall surface 31 of the pipe 30 so that the piezoelectric element 21 and piezoelectric element 22 face each other in a vertical direction relative to the longitudinal direction of the pipe 30, and the piezoelectric element 23 and the piezoelectric element 24 face each other in a diagonal direction relative to the longitudinal direction of the pipe 30, namely to face each other in the direction at angle θ (0° < θ < 90°). In this case, the ultrasound

wave 101 transmitted from the piezoelectric element 21 is not only received by the piezoelectric element 22, but also part of it is reflected by the inner wall surface 32 of the pipe 30 and the reflected wave 102 is received by the piezoelectric element 21. Further, the ultrasound wave 103 transmitted from the piezoelectric element 23 is received by the piezoelectric element 24, and the ultrasound wave 104 transmitted from the piezoelectric element 24 is received by the piezoelectric element 23.

【0014】 The switching device 4 is for switching between the send status and the receive status of each piezoelectric elements 21 through 24 of the sensors 1 through 3. Here, the send status means that the send signal outputted from the transceiver 5 is inputted to the piezoelectric elements 21 through 24, while the receive status means that the receive signals outputted by the piezoelectric elements are inputted to the transceiver 5.

【0015】 The transceiver 5 outputs send signal of prescribed frequency and voltage to the piezoelectric elements 21 through 24 under send status via the switching device 4, and also receives receive signals from the piezoelectric elements 21 through 24 under receive status via the switching device 5, amplifies the receive signals and outputs them to the gate circuit 6.

【0016】 The gate circuit 6 selects appropriate signals, from the receive signals from the transceiver 5, which are necessary for measurement and outputs them to the counter 7. The counter 7, controlled by the trigger

signal outputted by the control unit 9 at the start of the measurement and receive signals outputted from the gate circuit 6, obtains the transmission time t_1 of ultrasound wave 101 from the piezoelectric element 21 to the piezoelectric element 22; the transmission time t_2 of ultrasound wave 102 transmitted from the piezoelectric element 21, reflected by the inner wall 32 of the pipe 30, and returns to the piezoelectric element; and the transmission time difference Δt between the transmission time of ultrasound wave 103 sent from the piezoelectric element 23 to the piezoelectric element 24 and the transmission time of ultrasound wave 104 sent from the piezoelectric element 24 to the piezoelectric element 23.

【0017】 The calculation unit 8 is made up from an acoustic velocity measuring unit 10, a temperature measuring unit 11, and a current velocity measuring unit 12. The acoustic velocity measuring unit 10 measures the acoustic velocity C based on the transmission times t_1 and t_2. The temperature measuring unit 11 measures the temperature T of the fluid based on this acoustic velocity C. The current velocity measuring unit 12 measures the current velocity V of the fluid based on the transmission time difference Δt and the acoustic velocity C.

【0018】 The control unit 9 controls this ultrasound temperature current meter and controls the operation of the switching device 4, the transceiver 5, the gate circuit 6, the counter 7, and the calculation unit 8. The flow of the temperature and current velocity measurement using this ultrasound temperature meter is explained next.

【0019】 First, the temperature T of the fluid is measured as follows. The control unit 9 controls the switching device 4 to change the piezoelectric element 21 of the sensor 1 to a send status and change the piezoelectric element 22 of the sensor 2 to a receive status. Under this condition, when the transceiver 5 outputs send signal, ultrasound wave 101 is transmitted from the piezoelectric element 21, and, at the same time, the counter 7 starts the count operation for measuring time. Here, after the piezoelectric element 21 has transmitted ultrasound wave 101, the status of the piezoelectric element 21 is changed to a receive status by the switching device 4 under control of the control unit 9.

【0020】 The ultrasound wave 101 transmitted from the piezoelectric element 21 is transmitted in a vertical direction relative to the longitudinal direction of the pipe 30, i.e., relative to the flow direction of the fluid, through the fluid and received by the piezoelectric element 22. The piezoelectric element 22, in response to the received ultrasound wave 101, outputs receive signal 201. This receive signal 201 is inputted to the transceiver 5 via the switching device 4, appropriately amplified, and inputted to the counter 7 via the gate circuit 6. The counter 7 obtains the count, at the time the receive signal 201 was received, as the data indicating the transmission time t_1, and outputs this value to the acoustic velocity measuring unit 10 of the calculation unit 8.

【0021】 A part of the ultrasound wave 101 transmitted from the piezoelectric element 21 is reflected by the inner wall 32 of the pipe

30. This reflected wave 102 is received by the piezoelectric element 21 whose status had been switched to the receive status. The piezoelectric element 21 outputs receive signal 202 in response to the reflected wave 102. This receive signal 202 is inputted to the counter 7 via the switching device 4, the transceiver 5, and gate circuit 6. The counter 7 obtains the count, at the time the receive signal 202 was received, as the data indicating the transmission time t_2, and outputs this value to the acoustic velocity measuring unit 10. The transmission time t_2 indicates the time which the ultrasound wave 101 transmitted from the piezoelectric element 21 took to travel excluding through parts in the fluid such as the sensors 1, 2, and the pipe 30. Thus, it is possible to obtain the transmission time of the ultrasound wave in the fluid by subtracting t_2 from t_1.

【0022】 The acoustic velocity measuring unit 10 measures the acoustic velocity C in the fluid at the time of measurement based on the transmission times t_1 and t_2. In this case, the ultrasound wave 101 transmitted from the piezoelectric element 21 travels in a vertical direction relative to the flow direction 33 of the fluid. Thus, the transmission time t_1 is not influenced by the current velocity V. Thus, if the inner diameter of the pipe is set to L_1, the acoustic velocity C can be obtained by the following equation.

【0023】

$$C = L_1 / (t_1 - t_2) \qquad \dots (1)$$

The temperature measuring unit 11 measures the temperature T of the fluid

based on this acoustic velocity C. In this case, the temperature T can be obtained by the following equation. Here, "f" is a function of temperature T relative to the acoustic velocity C, and is determined by the type of the fluid.

【0024】

$$T = f\ (C) \qquad \dots (2)$$

Next, the current velocity V of the fluid is measured as follows. The control unit 9 controls the switching device 4 to change the piezoelectric element 22 of the sensor 1 to a send status and change the piezoelectric element 24 of the sensor 3 to a receive status. Under this condition, when the transceiver 5 outputs send signal, ultrasound wave 103 is transmitted from the piezoelectric element 23, and, at the same time, the counter 7 starts the count operation. Here, after the piezoelectric element 23 has transmitted ultrasound wave 103, the status is changed to a receive status by the switching device 4 under control of the control unit 9.

【0025】 The ultrasound wave 103 transmitted from the piezoelectric element 23 travels in the fluid at angle θ relative to the flow direction 33 of the fluid and is received by the piezoelectric element 24. The piezoelectric element 24 outputs receive signal 203 in response to the reflected wave 103. This receive signal 203 is inputted to the counter 7 via the switching device 4, the transceiver 5, and gate circuit 6. The counter 7 stores the count at the time it received the receive signal 203 as the transmission time t_3 of the ultrasound wave 103.

【0026】 On the other hand, when the piezoelectric element 24 receives the ultrasound wave 103 from the piezoelectric element 23, the control unit 9 changes the piezoelectric element 24 to a send status and the piezoelectric element 23 to a receive status respectively via the switching device 4. And the by outputting a send signal from the transceiver 5, it makes the piezoelectric element 24 to transmit ultrasound wave 104 and it makes the counter 7 to start its counting operation.

【0027】 The ultrasound wave 104 transmitted from the piezoelectric element 24 travels through the fluid in the direction opposite to that of the ultrasound wave 103 transmitted from the piezoelectric element 23, and is received by the piezoelectric element 23. The piezoelectric element 23 outputs receive signal 204 in response to the reflected wave 104. This receive signal 204 is inputted to the counter 7 via the switching device 4, the transceiver 5, and gate circuit 6.

【0028】 When the receive signal 204 is received, the counter 7 assigns the count value as the transmission time t_4 of the ultrasound wave 104. Then, the counter 7 obtains the transmission time difference Δt (= t_3 - t_4) from the stored transmission time t_3 and this transmission time t_4. Then, the counter 7 outputs this transmission time difference Δt to the current velocity measuring unit 12 of the calculation unit 8.

【0029】 The current velocity measuring unit 12 measures the current velocity V of the fluid based on this transmission time difference Δt and the acoustic velocity C measured earlier. In this case, let the angle of

flow direction 33 and the transmission direction of the ultrasound wave 103 be θ, and let the transmission distance through the fluid of the ultrasound wave 103 and 104 be L_2. Then, the current velocity V can be obtained by the following equation. 【0030】 【Equation 1】

$$V = \Delta t \frac{C^2 - V^2}{2 L_2 \cos\theta} \fallingdotseq \Delta t \frac{C^2}{2 L_2 \cos\theta} \quad \cdots (3)$$

(where, C > V.)

【0031】 In this manner, the ultrasound temperature current meter of this embodiment obtains the transmission time of the ultrasound wave 101 excluding the influence from the thickness of the pipe 30 by subtracting the transmission time t_2 (of the reflected wave 102 which was transmitted from the piezoelectric element 21, reflected by the inner wall surface 32 of the pipe 30, and returned to the piezoelectric element 21) from the transmission time t_1 (of the ultrasound wave 101 transmitted from the piezoelectric element 21 to the piezoelectric element 22). Here, the transmission direction of the ultrasound wave 101 transmitted from the piezoelectric element 21 is vertical relative to the flow direction 33 of the fluid. Thus, the transmission time is not influenced by the flow velocity V of the fluid. Thus, an accurate acoustic velocity C can be obtained at the measurement time based on the transmission time of the ultrasound wave 101 in the fluid. Further, the accurate temperature T of the fluid can be obtained from this acoustic velocity C.

【0032】 In this manner, it is possible to obtain the acoustic velocity

C and the temperature T easily and accurately without having to bore a hole in the pipe 30 as was conventionally necessary and without being influenced by the thickness of the pipe 30 or the change in the thickness due to the temperature variation.

【0033】 Further, by measuring the current velocity V of the fluid based on the transmission time difference Δt between the transmission time t3 of the ultrasound wave 103 transmitted form the piezoelectric element 23 to the piezoelectric element 24 and the transmission time t4 of the ultrasound wave 104 transmitted from the piezoelectric element 24 to the piezoelectric element 23 and above-mentioned measured acoustic velocity C, it is possible to obtain the accurate current velocity V even when the temperature T and the current velocity V of the fluid changes widely over time.

【0034】 【Advantageous Effect of the Invention】

As was explained above, this invention enables measurement of temperature and current velocity of the fluid easily and with high accuracy by obtaining the acoustic velocity and the temperature of the fluid based on the in-fluid transmission time of the ultrasound wave transmitted in a vertical direction relative to the flow direction of the fluid in the pipe, and by obtaining the current velocity of the fluid based on this acoustic velocity.

[BRIEF DESCRIPTION OF THE DRAWINGS]

【Figure 1】 A block diagram showing the configuration of the ultrasound temperature current meter of an embodiment of this invention.

【Figure 2】 A diagram to explain the actual configuration of the sensors in Figure 1 and their placement on the pipe.

【Explanation of codes】

1 – 3 … Sensor

4 … Switching device

5 … Transceiver

6 … Gate circuit

7 … Counter

8 … Calculation unit

9 … Control unit

10 … Acoustic velocity measuring unit

11 … Temperature measuring unit

12 … Current velocity measuring unit

21 - 24 … Piezoelectric element

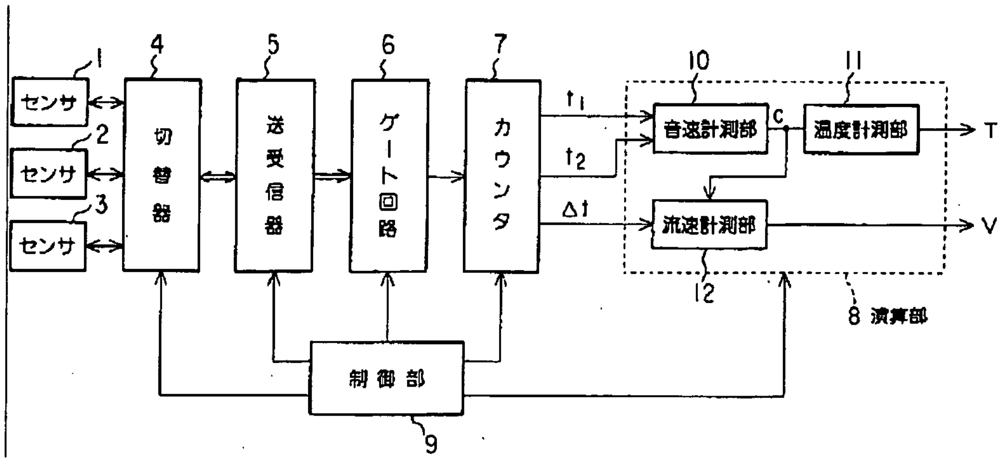
30 … Pipe

31 … Outer wall surface

32 … Inner wall surface

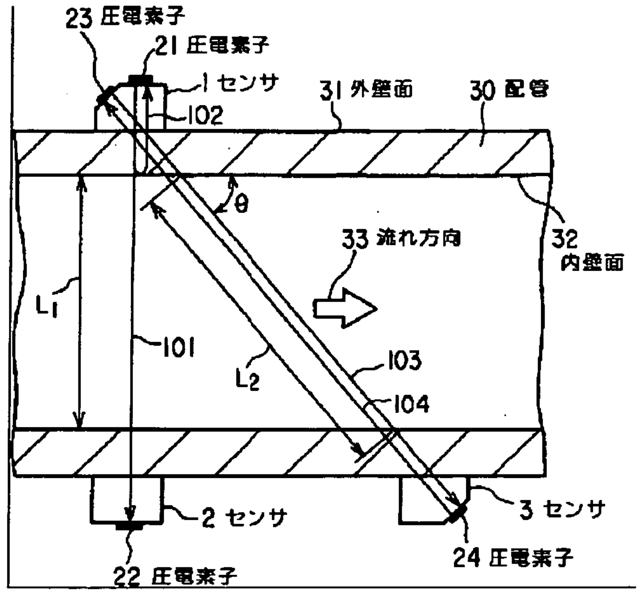
33 … Flow direction

【Figure 1】



1- Sensor
2- Sensor
3- Sensor
4- Switching device
5- Transceiver
6- Gate circuit
7- Counter
8- Calculation unit
9- Control unit
10- Acoustic velocity measuring unit
11- Temperature measuring unit
12- Current velocity measuring unit

【Figure 2】



1- Sensor
2- Sensor
3- Sensor
21- Piezoelectric element
22- Piezoelectric element
23- Piezoelectric element
24- Piezoelectric element
30- Pipe
31- Outer wall surface
32- Inner wall surface
33- Flow direction